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Method for operating a drive system

The invention relates to a method for operating a drive system for a vehicle comprising an internal combustion engine and an electric machine, it being possible to accelerate a driveshaft of the internal combustion engine by means of the electric machine.

A starter/generator for an internal combustion engine of a motor vehicle, which is known from the patent document EP 0 876 554 B1, comprises an electric three phase machine which performs starter and generator functions. In addition, the electric machine can effect or assist acceleration and/or braking of the driveshaft, particularly in order to accelerate or brake a vehicle and/or in order to prevent slipping of a driven wheel in the context of anti-slip control by braking the internal combustion engine or at least one driven wheel. The electric machine can also be used to reduce rotational non-uniformities of the driveshaft by virtue of the fact that for compensation purposes, it generates a rapidly alternating opposite phase torque.

In the case of low volume internal combustion engines in the field of automobiles, the reduction in torque which results from the reduced stroke volume is often compensated for by means of pressure charging, particularly by means of an exhaust gas turbocharger. In the case of an exhaust gas turbocharger, the turbine rotates more quickly as the exhaust gas flow increases. This results in an increase in the charge pressure, that is to say the pressure with which the air is forced into the combustion space of the internal combustion engine. The effect of the exhaust gas turbocharger is, however, restricted at low engine

speeds and in part-load situations because of the wide span of exhaust gas and the low speed of the exhaust gas flow. This results in poor starting performance of internal combustion engines of low stroke capacity in particular (so-called "turbo lag"). The use of variable turbine geometry is difficult to implement in the case of a spark ignition engine with its high exhaust gas temperatures and geometric combustion, and results in only an insignificant increase in the starting torque. Solutions having electrically assisted pressure charging systems or electrically assisted exhaust gas turbochargers are technically highly complex.

Considerable dead times occur, particularly in conjunction with automated clutch systems, because of the low efficiency of the exhaust gas turbocharger at low rotational speed when the vehicle starts and during shifts until the clutch can engage. In this context it is assumed that, as is generally customary, a control unit, particularly an engine and/or transmission control unit, is provided which monitors the engine speed and allows complete engagement of the clutch only when the rotational speed has exceeded a certain limit value and in this way so-called "stalling" of the internal engine after the clutch has engaged cannot occur. In order to prevent the internal combustion engine stalling, the clutch is typically operated in a slipping manner until the internal combustion engine speed has reached a sufficiently high value.

It is an object of the invention to provide a method for operating a drive system for a motor vehicle which leads to short clutch engagement times, particularly in the low rotational speed range.

The object is achieved by means of a method having the

features of claim 1.

The method according to the invention is characterized in that when an upshift is initiated or in the event of an upshift, an idling rotational speed of the driveshaft is increased by the electric machine.

A starter/generator or motor/generator which is already provided in the motor vehicle and can be used in particular for stop/start operation is preferably used as the electric machine. The electric machine can drive the driveshaft by means of a belt provided for this purpose. It can however also be arranged directly on the driveshaft (so-called integrated arrangement). An electric three phase machine, particularly a synchronous machine, an asynchronous machine or a reluctance machine is preferably used.

A clutch can be engaged earlier, without the internal combustion engine "stalling", due to the assisting acceleration of the driveshaft by means of the electric machine, since the driveshaft rotational speed exceeds the limit driveshaft rotational speed, described in the introduction, for engaging the clutch, earlier thanks to the additional acceleration. A control unit therefore needs to keep the clutch operating in a slipping manner for less time than in the case of operation without an increase in idling rotational speed by the electric machine. Engagement of the clutch can be permitted correspondingly earlier.

Clutch engagement times when starting and during shifts can therefore be advantageously shortened both with manually operated and with automated clutch systems and shift systems. Faster and more comfortable starting and shifting behaviour can be obtained as a result.

The method according to the invention can advantageously be used to compensate for the so-called "turbo lag", described in the introduction, which is caused by the low efficiency of an exhaust gas turbocharging system at low rotational speeds. The method according to the invention can however also be used at relatively high rotational speeds.

Further advantageous embodiments of the invention are disclosed in the subclaims and the exemplary embodiments which are described in the following on the basis of the drawing, in which:

Fig. 1 shows a schematic illustration (not to scale) of a drive system and

Fig. 2 shows an exemplary graphic illustration of characteristics of vehicle-related variables with respect to time which result with and without acceleration assistance from the electric machine.

Figure 1 shows a drive system for a motor vehicle which comprises an internal combustion engine 1 and an electric machine 6. A driveshaft or crankshaft 4 is assigned to the internal combustion engine 1 and can be connected to a transmission shaft 5 of a transmission 2 by means of a clutch 3. The electric machine 6 is preferably arranged on an engine housing, which is not indicated in more detail, and can drive the driveshaft 4 of the internal combustion engine 1 by means of a belt 7. The electric machine 6 can thus, in addition to the internal combustion engine 1, set the driveshaft 4 in rotation and accelerate and/or brake the latter. The electric machine 6 is preferably supplied with electrical energy and controlled by a power electronic unit (not illustrated) and comprises a power converter

or power inverter, and a control unit which is not illustrated. The control unit can be a separate control unit. The control unit can however also be integrated in a drive system control unit which is already present, for example an engine control unit and/or a transmission control unit.

If the clutch 3 is disengaged for a shift, it is preferably not engaged again until the (idling) rotational speed of the driveshaft 4 has reached a sufficient value, so that after the clutch 3 has engaged, the driveshaft 4 is not braked to a value at which the internal combustion engine could "stall". A further control unit (not illustrated) therefore usually ensures that the clutch 3 is operated in a slipping manner until the rotational speed of the driveshaft 4 has reached a sufficiently high value at which the internal combustion engine cannot "stall" after the clutch 3 has engaged. This further control unit can be a separate control unit. The further control unit can however also be integrated in a drive system control unit which is already present, for example an engine control unit and/or a transmission control unit and/or a control unit for controlling the electric machine.

In the method according to the invention, the idling rotational speed of the driveshaft 4 is increased by means of the electric machine 6 when an upshift is initiated or in the event of an upshift to a value which prevents the internal combustion engine 1 from "stalling" when the clutch 3 is engaged.

By means of the method according to the invention, the idling rotational speed can be increased and thus a low efficiency of the turbocharger at low rotational speeds can be compensated for particularly when an exhaust gas

turbocharger (not illustrated), which has a low efficiency at low rotational speeds and which can thus only contribute a small amount to the increase in rotational speed/torque in this rotational speed range, is used to increase the charge pressure.

By way of example, figure 2 shows characteristic curves of the driveshaft rotational speed and of a vehicle speed with respect to time as they occur with and without acceleration assistance from the electric machine. The time is plotted on the abscissa. The rotational speed is plotted on the left ordinate and the vehicle speed is plotted on the right ordinate. The characteristic curves f_1 and f_2 are characteristic curves of the rotational speed, the rotational speed characteristic f_1 being produced with acceleration assistance from the electric machine and the rotational speed characteristic f_2 being produced without acceleration assistance from the electric machine.

The characteristic curves f_3 and f_4 are characteristic curves of the vehicle speed, the vehicle speed characteristic f_3 being produced with acceleration assistance from the electric machine and the vehicle speed characteristic f_4 being produced without acceleration assistance from the electric machine. The brake pedal is released at 0 seconds. Full throttle is applied at the time t_1. If an electric machine is used for drive assistance, this electrical assistance comes into effect from the time t_1 onwards.

Up to the time t_1, the rotational speed characteristics f_1 and f_2 have similar, nearly constant behaviour. However, while the rotational speed characteristic f_1 effected with the use of drive assistance from the electric machine already rises at the time t_1, the rise

in the rotational speed characteristic f_2 does not occur until approximately 0.08 seconds later. The motor vehicle with drive assistance from the electric machine correspondingly starts at the time t_2 (see vehicle speed characteristic f_3), while the motor vehicle without drive assistance from the electric machine does not start until a time t_3 (see vehicle speed characteristic f_3), t_2 being smaller than t_3. According to the vehicle speed characteristics f_3 and f_4, the motor vehicle with drive assistance from the electric machine reaches a higher speed at an earlier point in time than the vehicle without drive assistance from the electric machine.